Readiness for Self-driving Vehicles in Australia

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ARRB Group Ltd
Workshop Report

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Policy and regulatory response to, and physical preparations for, the rapid emergence of self-driving vehicles will influence Australia's competitiveness for many decades to come, yet there is a widespread belief that the nation is not ready for this development.

At its most recent (26th) biennial conference in Sydney, ARRB Group invited a number of key stakeholders to identify and discuss pressing issues associated with the emergence of self-driving vehicles. This workshop report collates the points raised and provides some analysis of the work required.

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Summary

It is recognised that policy and regulatory response to, and physical preparations for, the rapid emergence of self-driving vehicles[1] will influence Australia's competitiveness for many decades to come, yet there is a belief that the nation is not ready for this development.

The likely safety and economic benefits of self-driving vehicles are extensive. A number of existing agencies and stakeholders will need to adapt and in some cases revise their business models to remain viable. It is an important turning point – the challenges must be identified, understood and communicated and the consensus is that it requires extensive co-operation between government agencies and private sector organisations. New alternatives need to be found and integrated – rather than viewing components of the transport system (the road network, the vehicle and the user) in isolation.

At its 26th biennial conference, ARRB Group (ARRB) invited key stakeholders to participate in a roundtable discussion and featured self-driving cars as the topic for the closing plenary session. Interesting and divergent opinions raised at the conference sessions highlighted the need for this emerging technology to be better understood and it's far reaching impacts anticipated. In response ARRB has prepared this workshop report with a view to elucidating the issue. Key points and concerns surrounding self-driving vehicles include the road environment, human interaction with the technology, the impact on planning and public transport and the architecture of the digital systems required to integrate the network. This document provides some analysis of the considerable task at hand to be ready for self-driving vehicles and to enable their obvious benefits to be accrued for the national good.

[1] The term 'self-driving vehicles' has been used for consistency and is intended to include cars and commercial vehicles. It is recognised that the terms 'driverless vehicles', 'automated vehicles', 'autonomous vehicles' and 'connected vehicles' are also used in this field.

1 Introduction

1.1 Background

In October 2014, ARRB published the document 'Driverless Cars – Prospectus for Collaboration to Establish Infrastructure Needs and Benefits' (ARRB Group 2014a). Co-operation is sought from key stakeholders in investigating and forecasting what would be required for Australia to successfully meet the challenges associated with the emergence of self-driving vehicles – given that decisions and actions now will ultimately dictate Australia's state of readiness and hence, its international competitiveness.

The benefits of self-driving vehicles are considerable and are set out in detail in the prospectus and summarised in Section 2 of this report, but they will only be achieved if the nation is prepared – in many areas this will require research and collaborative thinking and action, most notably around the following questions:

- Can we expect a natural and smooth progression from the vehicles of today to an entire fleet of self-driving vehicles? (Will there be intermediate steps[2] – how long will it take and what is the range of technology options?)
- Will today's infrastructure provision need to change? (If so, how radically and how rapidly? What will future roads look like and how will we need to maintain them?)
- Will/should driving and its regulation (for example issues such as impairments) need to be substantially different?
- How will we best manage self-driving vehicles on road networks – will the current approach require fine tuning or major modification?
- How will self-driving vehicles integrate with existing systems and services e.g. car parking, public transport?
- Is it possible to accurately predict and understand what the legal liability issues might look like for self-driving vehicles (do we need/want a 'nominal driver') and what implications might this have?
- Who are the critical stakeholders that will need to lead and work together to plan the way ahead and have sufficient influence to make things happen? (Which existing organisations will need to adapt their service and/or business models following the emergence of self-driving vehicles?)

In the prospectus ARRB identified a 3-year, 3-stage program in preparation for the emergence of self-driving vehicles:

[2] Section 2 introduces the stages of autonomy developed by ISO and SAE

To build on the prospectus, ARRB scheduled two sessions on self-driving vehicles during its 26th Conference, held in Sydney from 19 to 22 October 2014.

A roundtable was held on 22 October, facilitated by Mr Ian Webb, the Chief Executive of Roads Australia. Participants were invited from:

- governments and national agencies
- industry – associations, automotive, insurance, Information and Communication Technology (ICT), suppliers
- researchers – universities, Co-operative Research Centres (CRCs), National Information and Communication Technology Australia (NICTA)
- standards development organisations, e.g. Standards Australia
- other sectors – public transport, police and national security, vulnerable road user groups.

The invitees and their organisations are listed in Appendix A.

The objective was the establishment of a formal group on self-driving vehicle issues, comprising a Project Board and Project Management Committee, within an agreed scope and a terms of reference (ToR). The main benefit would be that focal point was created.

The roundtable was successful in identifying a number of stakeholder/industry specific issues for further consideration and understanding, as well as examining logistical aspects of the formal leadership group – i.e. items for the ToR, enabling mechanisms, building on the developments and progress of others and best methods for collaboration and communication.

Mr Gerard Waldron (Managing Director of ARRB Group) chaired a formal Conference session on self-driving vehicles, with the following speakers providing insight into the main issues facing agencies in Australia, both in preparation and operation, including on-going safety and management considerations:

- Mr Garry Bowditch, CEO of the SMART Infrastructure Facility at the University of Wollongong – on land use and network planning issues and integration with other modes of transport
- Dr Charles Karl, Technical Leader and Manager, Congestion, Freight and Productivity at ARRB Group – on international developments (e.g. Europe, USA, Japan) on self-driving vehicles and challenges in Australia
- Mr David Pickett, Certification & Engineering Manager at Volvo Cars Australia – on advances in vehicle safety technology and how these are currently being developed largely independently of road agencies
- Mr Craig Moran, General Manager – Traffic Management at Roads and Maritime Services, NSW – on the challenges facing road agencies construction and maintenance, including user expectations and access to the system
- Ms Penny Gale, General Manager – Public Affairs of the Royal Automobile Association of South Australia – on the concerns of motoring club members and the wider community in the safety of self-driving vehicles, especially during transition towards an entire fleet of self-driving vehicles.

An interesting delegate observation and Q&A session followed.

The following sections reinforce the potential benefits of self-driving vehicles (hence illustrating the importance of the discussion) and the main pressure points. The factors and issues in each of these points are then suggested, along with ideas on how they might be integrated and ultimately overcome.

2 Self-driving vehicles – why is this so important?

Self-driving vehicles are no longer science fiction – they have become a reality that brings many issues to be considered and addressed in the future. Not least, road assets and infrastructure planned and being built today will predominantly be used by self-driving vehicles during the course of their design life and are likely to require some reconsideration in light of this.

Self-driving vehicles are about mobility and access, providing new opportunities for people to interface with the transport network. The future could see:

- a two to five-fold increase in road network efficiency
- as close to Vision Zero and a Safe System as can reasonably be achieved
- a reduction in vehicle emissions and other environmental benefits
- complete network integration to minimise every road user's door-to-door journey
- a reduction in road space, parking and other related infrastructure requirements
- road freight cost savings of as much as 30% or more.

Major steps towards self-driving vehicles are taking place. Safety systems are capable of keeping vehicles within a defined lane and braking and accelerating with traffic to intervene to avoid a collision. Road safety research and recent self-driving vehicle reports (*Eno Center for Transportation, 2013*) states that 90% of all accidents have a human contributory factor, not least distraction and lapses in concentration. The vision of the *National Road Safety Strategy, 2011-20* 'No person should be killed or seriously injured on Australia's roads' will likely be achieved by this emerging technology, rather than behavioural changes. We can address some of these issues now, but many more when self-driving vehicles are fully implemented for road transport. However, to optimise the benefits, vehicle systems will need to be in constant communication with each other (V2V) and the road environment (V2I and I2V). This will require dedicated communication bandwidths for these interactions to be allocated, and compatibility of technology from the USA, Europe and Asia will be key to achieving safety outcomes.

Australia will act as a consumer of the self-driving vehicular technology. The size of our market and our diminishing local auto industry means that our task must be focussed on:

- **Legislative framework and trials** – a common, combined approach by all jurisdictions
- **Network optimisation** – the roads of today will not provide the full network potential
- **Compatibility** – vehicles, infrastructure and data sharing working together
- **Liability** – managing the transition of responsibility from human to machine.

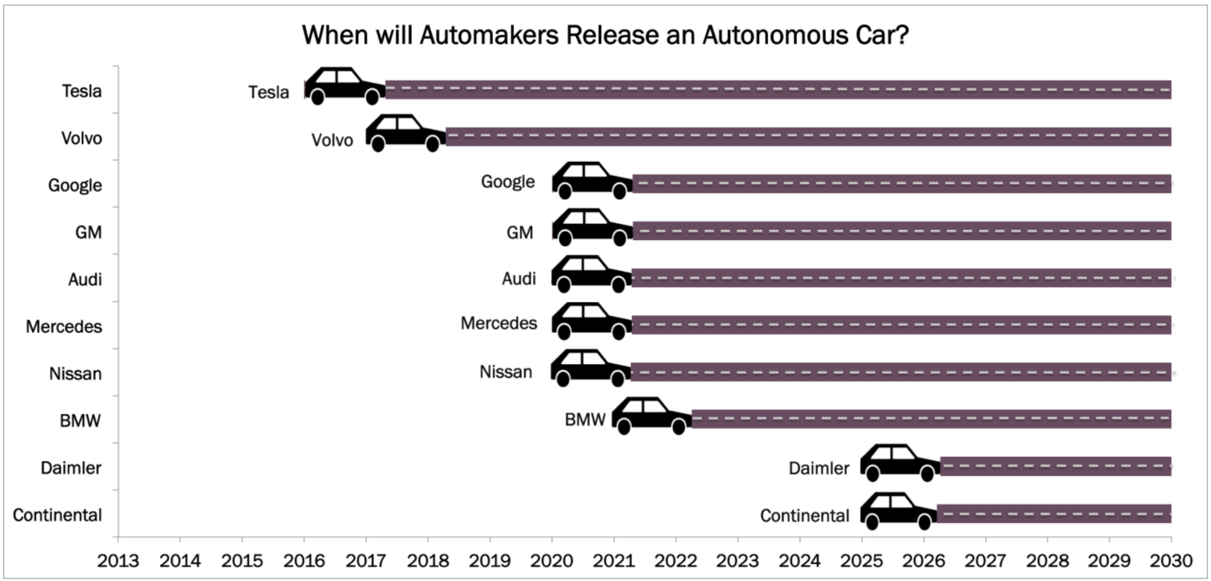
Up-to-date knowledge of the progress of other key countries is required to ensure Australia gets the most functional mix of compatible technology, local developments and innovation, as well as having the regulatory framework to use the technology.

Falling behind the rest of the world with a wait and see approach may see Australia's inherent competitive disadvantage widen. Instead, self-driving vehicles should be viewed as an opportunity to close the gap on the rest of the developed world. For instance, a dramatic decrease in the cost of road freight by as much as 30% is thought possible by taking the driver out of our already high-productivity line-haul trucks. We must also understand that *smart vehicles on ill-prepared infrastructure* can do little more than perform the driver's role more safely. To provide the full benefit to society, **smart vehicles running on smart infrastructure must be the target.**

Travel inefficiencies inherent in Australia's sprawling urban environments can be addressed by self-driving cars. High quality public transport to outer urban area hubs will largely depend on these publically/privately owned self-driving fleet vehicles as the cost of using self-driving vehicles becomes cheaper than private ownership and largely comparable to traditional public transport. The challenge is to ensure all public transport users (whether old, young or disabled) can travel directly from A to B in maximum safety at any time of day.

Predicting the timeframe of an entire fleet of self-driving vehicles and accurately integrating them with traditional public transport is essential for a functioning city of the near future. However, the uncertainties surrounding the optimum solution are significant – will more trains be needed? Will tram systems still have a role? Will less train stations be needed? Will there need to be high speed rail links between suburban car-rail hubs? And perhaps a more fundamental question – what will the user demand for public transport be with the emergence of self-driving vehicles?

The best estimate thus far is that full- functioning self-driving vehicles will be a significant part of the road fleet by 2030, with most predicting early 2020's for first vehicle releases (Figure 1). Interested parties have predicted that such vehicles will be within a shared-use/fleet model, rather than private ownership. This raises the question of how do we understand and model the impact of fleets of self-driving cars to protect-long term infrastructure investments?



Source: ARK Investment management (2014)

Figure 1: Release timing of self-driving cars from various manufacturers

Coordinating the key stakeholders is therefore a priority, helping to identify the pressure points that can slow or jeopardise transition. Working together now to shape, plan and legislate for the future will prevent false starts, missed opportunities and redundancy. Providing a common voice and thoughtful advice to regulators, asset owners and policy makers must be the goal as the demands of a rapidly evolving network materialise.

Australia also has sixty-seven different car brands, much greater than places like the United States, making Australia an ideal test environment to encourage widespread industry co-operation. Australians are the least likely to have previously heard of self-driving vehicles, but the most likely to have a positive view regarding such vehicles (UMTRI, 2014). The opportunity for Australia to be an early adopter of this technology is considerable with all the inherent benefits it is likely to bring.

SAE level	SAE name	SAE narrative definition	Execution of steering and acceleration/ deceleration	Monitoring of driving environment	Fallback performance of *dynamic driving task*	System capability (*driving modes*)	BASt level	NHTSA level
Human driver **monitors the driving environment**								
0	**No Automation**	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a	Driver only	0
1	**Driver Assistance**	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes	Assisted	1
2	**Partial Automation**	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes	Partially automated	2
Automated driving system **("system") monitors the driving environment**								
3	**Conditional Automation**	the *driving mode*-specific performance by an *automated driving system* of all aspects of the *dynamic driving task* with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes	Highly automated	3
4	**High Automation**	the *driving mode*-specific performance by an *automated driving system* of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes	Fully automated	3/4
5	**Full Automation**	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**		

Source: SAE International (2014)

Figure 2: Levels of autonomy defined by SAE International

SAE International has defined the six levels of autonomy (Figure 2) that detail the transition from full human control at *level 0*, to full automation at *level 6.* Currently we see *levels 0 and 1* on roads and an increasing number of *level 2* automation vehicles, albeit with the functionality of driving with hands off the steering wheel disabled. Figure 3 describes in detail the separate roles of the driver and the system for the different levels of autonomy.

Level of Driving Automation	Role of *Human Driver*	Role of System
***HUMAN DRIVER* MONITORS DRIVING ENVIRONMENT**		
Level 0 - No Automation	• Monitors *driving* environment • Executes the *dynamic driving task* (steering, accelerating, braking)	• No active automation (but may provide warnings)
Level 1 - Driver Assistance	• Monitors *driving* environment • Executes either longitudinal (accelerating, braking) or lateral (steering) *dynamic driving task* • Constantly supervises *dynamic driving task* executed by driver assistance system • Determines when activation or deactivation of driver assistance system is appropriate, except for systems that automatically intervene in an emergency • Takes over immediately when required	• Executes portions of the *dynamic driving task* not executed by the *human driver* (either longitudinal or lateral) when activated • Can deactivate immediately with request for immediate takeover by the *human driver*
Level 2 - Partial Automation	• Monitors *driving* environment • Constantly supervises *dynamic driving task* executed by partial automation system • Determines when activation or deactivation of partial automation system is appropriate, except for systems that automatically intervene in an emergency • Takes over immediately when required	• Executes longitudinal (accelerating, braking) and lateral (steering) *dynamic driving task* when activated • Can deactivate immediately with request for immediate takeover by the *human driver*
***AUTOMATED DRIVING SYSTEM* MONITORS DRIVING ENVIRONMENT**		
Level 3 - Conditional Automation	• Determines when activation of *automated driving system* is appropriate • Takes over upon request within lead time • May request deactivation of *automated driving system*	• Monitors *driving* environment when activated • Permits activation only under conditions (use cases) for which it was designed • Executes longitudinal (accelerating, braking) and lateral (steering) portions of the *dynamic driving task* when activated • Deactivates only after requesting *driver* takeover with a sufficient lead time • May, under certain, limited circumstances, transition to *minimal risk condition* if *human driver* does not take over • May momentarily delay deactivation when immediate human takeover could compromise safety
Level 4 - High Automation	• Determines when activation of *automated driving system* is appropriate • Takes over within lead time, if requested • May request deactivation of *automated driving system* • Some applications in this category may not entail a human driver.	• Monitors *driving* environment when activated • Permits activation only under conditions (use cases) for which it was designed • Executes longitudinal (accelerating, braking) and lateral (steering) portions of the *dynamic driving task* when activated • Initiates deactivation when design conditions are no longer met • Deactivates only after *human driver* takes over • Transitions to *minimal risk condition* if *human driver* does not take over • May momentarily delay deactivation when immediate human takeover could compromise safety
Level 5 - Full Automation	• May activate *automated driving system* • May request deactivation of *automated driving system* • This category may not entail a human driver.	• Monitors *driving* environment when activated • Executes longitudinal (accelerating, braking) and lateral (steering) portions of the *dynamic driving task* when activated • Deactivates only after *human driver* takes over or *vehicle* reaches its destination • Transitions to *minimal risk condition* as necessary if failure in the *automated driving system* occurs • May momentarily delay deactivation when immediate *human driver* takeover could compromise safety

Source: SAE International (2014)

Figure 3: The roles of the driver and the system presented by SAE International.

3 Road environment – planning, provision, operation and maintenance

This section covers a range of road environment issues as they relate to the emergence of self-driving vehicles, from transport and network planning through to network operation and maintenance issues.

Topic Road environment – road network/transport planning, provision, operations (including traffic management) and maintenance
Current position, future issues and challenges • **Transport planning and policy** – it is recognised that self-driving vehicles provide an opportunity to be an agent of social change – i.e. the way transport is provided in Australia can secure more functional, productive networks. There is a great opportunity to integrate the emergence of self-driving vehicles with innovative ways of network operation, for example, encouraging greater non-peak usage (or penalising peak usage). In this way, self-driving vehicles can act as a catalyst to more effective road pricing. However, there are also unknowns. For example, it remains to be seen whether the comfort and functionality of self-driving vehicles will in practice encourage longer journeys. This could mean longer journeys commuting over greater distances with the adverse effect of a greater propensity for urban sprawl. The shape/form of public transport is open to question – e.g. will it remain (hub to hub) or gradually change to 'home door' to 'work door' services? It has been suggested that self-driving vehicles will not be the whole answer and that modes in and out of each urban centre will be slightly different, depending on traditional systems (e.g. commuter rail), self-driving vehicle ownership and availability etc. This suggests that network providers should not rule out options to 'put all their eggs in one basket', i.e. self-driving vehicles will have a unique role to play just as much as other forms of personal and public transport. Providing realistic travel choices will remain an objective of transport planners and network providers. The decisions reached now and in the short-term in response to the challenges outlined need to be reflected in long term transport planning. • **Traffic management and user expectation** – it is suggested that the emergence of self-driving vehicles will inevitably provide greater capacity, especially useful in peak periods, which in turn may intensify activity in city centres/CBDs. However, there is some thought that a maximum capacity still physically exists and hence only a limited effect may result. This highlights the need to have a good understanding of the demand for self-driving vehicles, including developments internationally. Such vehicles may even give network providers the opportunity/potential to determine which routes are to be followed by vehicles at certain times of the day and/or based on various traffic parameters and network pressures and needs. There also remains uncertainty as to how car parking provision will change – with respect to the impact on time spent finding spaces, numbers of spaces required to be provided etc. It has been suggested that network and traffic managers have seen similar challenges before and have reacted well to them (e.g. demand for bus lanes in Sydney responding to demand and also contributing to network needs and realistic transport choices for the public) and this is merely a further, natural progression – the aim being to integrate self-driving vehicles into the network with minimum impact and disruption. Currently network users (road agency customers) want safer, more efficient and more reliable road networks, but their expectations may change with the emergence of self-driving vehicles – can we reasonably foresee what these changed expectations are going to be and will this require higher or lower levels of service being required or provided? Road agencies already understand that the customer needs to be at the centre of their attention and understanding; the focus must be on performance and outcomes rather than introducing technology for its own sake.

- **Intelligent transportation systems (ITS)** – much good work has taken place on co-operative-ITS (C-ITS) at a national level (through Austroads) and further progress is widely seen as an essential and logical development ahead of the emergence of self-driving vehicles. C-ITS uses established communications technology that is very cost-effective. The challenge is now to accelerate C-ITS, including assessing closely what developments are happening overseas (as it was felt that Australia may be up to 5-7 years behind some countries and behind in certain situations), and there may be benefits associated with harmonisation. Practitioners remain confident that developments in this field will bring about significant improvements in traffic capacity and flow and safer, more sustainable road networks. Some issues are foreseen with accuracy and capability of current mapping of networks to assist self-driving vehicles. These will need to be resolved, but will most likely involve private companies, rather than government agencies.

- **Infrastructure design and provision –** how self-driving vehicles will be catered for, and what the road environment will ultimately look like needs to be resolved (e.g. geometrical features, lane widths and intersections, provision of roadside barriers, traffic signals, surfacing materials etc.). There is mixed opinion as to whether the road will be substantially different or not in terms of its look or the materials and techniques used, i.e. will dedicated infrastructure (e.g. lanes for self-driving vehicles only) be necessary and/or the best option or can existing infrastructure be modified or in some cases used without modification, to the same overall effect. Whether certain roads will become obsolete and hence need to be decommissioned will also require consideration. Land requirements for new/future roads will almost certainly change and will need to be verified over time. It is already known that road agencies can provide infrastructure (e.g. line markings, signs) that can be 'read' successfully by vehicles (V2I), but a decision needs to be taken now on whether roads at the planning or partial construction phase at the current time need to be suited for the infrastructure (and if so how to do it). It has been suggested that the most logical approach is for road agencies to agree and communicate a number of stages or visions for a road, i.e. from current provision through the transition to a fully self-driving fleet. By default, this will also require a minimum level of infrastructure provision to be determined under which self-driving vehicles can operate. Australia's vast (often remote) and typically ageing infrastructure will be need to be given due consideration.

- **Infrastructure operation** – it is likely that current service level requirements will no longer be appropriate and will require adjusting for self-driving vehicles. The network will still need to be able to reconfigure/adjust when required for roadworks and upgrades etc. This will ultimately mean finding effective ways of transmitting temporary or short-term locational data to self-driving vehicles close by (i.e. short-term I2V).

- **Safety** – it is expected that the road toll will reduce as a result of any substantial move to self-driving vehicles. However, by how much? There is a concern that any crashes could be catastrophic, but as seems more likely, redundancy in vehicle systems (required by legislation and regulation) will have a major role to play in preventing major incidents that might otherwise be caused by a computer failure.

- **Infrastructure maintenance** – all infrastructure that is provided to be specifically linked to self-driving vehicles (i.e. V2I) will need to be routinely inspected and maintained.

- **Funding** – if, as anticipated, the number and type of vehicles will change then the funding for infrastructure provision and maintenance (currently rates, taxation and in some instances, direct charging) may also need to be reconsidered.

Key stakeholders/agencies

Likely to include, but not restricted to: federal and state governments including transport agency, legal/justice departments, police and legal professionals, advocacy groups and vehicle manufacturers.

Potential research areas and solutions

Increased productivity of the road network is a major feature of self-driving technology. Some of the benefits that have been identified (but may ultimately require verification) are:

- unlocking/freeing up the space (distance) between vehicles and on existing roads
- the need for less and/or different infrastructure provision; dedicated platoon lanes for heavy vehicles could yield 10-15% efficiency gains, but may need stronger pavements to accommodate the increased loading. (*Eno Center for Transportation, 2013*)
- the need for less road space overall
- minimising the time spent looking for parking
- negating the requirement to park a car near the occupant's destination
- total traffic point-to-point management (optimised routing for all vehicles)
- reduced travel times; computational traffic modelling (*Dresner and Stone, 2008)* gives upper estimates that intersection delays could be all but eliminated once market penetration of self-driving cars reaches 90%
- travelling without risk of collision and the consequent effects of such incidents on traffic congestion
- better fuel economy of much smaller and more consistently operated vehicles.

It has been suggested that the most tangible and visible returns will most likely happen later, towards the complete self-driving fleet, i.e. as the road network adjusts to the vehicles and vice versa. However, this should not prevent planning and innovation now, with trials being prioritised to enable a full understanding of the challenges and opportunities ahead. This is lacking at the current time within Australia. Creating a uniform national approach to standards and regulation at an early stage will also help alleviate future compatibility issues. The transitional phase towards a fully self-driving fleet, actively communicating to the road network, is likely to last for more than a decade.

Action required to:

- Map the way ahead to ensure true integration between traffic management, ITS, and self-driving vehicles.
- Ensure that transport agencies determine the need for a consistent national approach and develop guidelines.
- Decide on the roles of public/private ownership and control of the network (vehicle routing, etc.).

Analysis/commentary

It is considered inevitable that all road environments will need to change with the advent of self-driving vehicles. Whether Australia becomes a developer of innovative infrastructure products and solutions, or a consumer, is not clear.

Integration and co-operation between practitioners working in transport planning, network operations and infrastructure asset management is essential if all the benefits of self-driving vehicles are to be gained and networks operate to peak efficiency. Network mapping is likely to remain the domain of private companies and may well extend to include elements of routing, live traffic modelling, flow navigation, lane selections, etc. Adaptive cruise control (ACC) alone in modelling conducted *(Schladover et al. 2012)* at adoption rates of 10%, 50% and 90% gives lane capacity increases of 1%, 21% and 80%. This modelling essentially involves current technology installed on many new cars.

4 Vehicle issues

This section covers the vehicular issues affecting the users of self-driving vehicles, from vehicle design (i.e. what will totally self-driving vehicles look like) to vehicle ownership models.

Topic Vehicle issues – The vehicle itself, control, data security, ownership model and automotive groups
Current position, future issues and challenges • **Terminology –** the terms 'self-driving', 'connected', 'automated' and 'autonomous' are all being used in this field, and it has been suggested that there is a need to standardise on one term. There is alas a need to break the misperception that such vehicles run on rails/tracks and/or require extremely accurate positional systems to operate, or they might run out of control. • **What will a self-driving vehicle look like?** – it is expected that in the short to medium term self-driving vehicles will appear similar to today's vehicles – not least to retain a degree of familiarity and in many cases reflecting an affinity for cars and motoring. In the longer-term it is likely that designs/forms will be modified, possibly to an extent that such vehicles become barely recognisable. It is to be determined whether self-driving vehicles will be used over longer distances only; similarly whether the vehicles will be larger and offer greater levels of comfort and functionality, or smaller and be basic and utilitarian. As with their form, it is likely that it will take time for major changes to be made to the way in which self-driving vehicles are propelled/powered. • **Who will own self-driving vehicles?** – there is an expectation that private ownership of vehicles will decrease significantly with the emergence of self-driving vehicles, with the knock-on effect of raising disposable income, although this will need to be verified. A suggestion has been made that in the future most self-driving vehicles will be owned by commercial organisations/private sector entities, and may even be motoring clubs, as their business models also adapt. • **How fast will the change be? –** as indicated in Section 2 of this report, a gradual evolution towards the entire fleet being self-driving vehicles appears most likely, as more capability and technology comes on line. This will mean a mixed fleet for some time to come. It has been suggested that network owners and operators should consider and plan for it - as this is a foreseeable shift. • **Vehicle manufacturers are tending to focus on in-vehicle safety systems** – these include V2V communications and associated safety outcomes (as Volvo describes it 'removing the driver from the impact'), rather than necessarily looking to develop and market totally self-driving vehicles. It is recognised that if safety systems become too sensitive the temptation will be for drivers to manually turn the systems off (where possible) or override and disable them in some other way. More widely, it is recognised that there is a need to consider how self-driving vehicles will most effectively tune to, and communicate with, infrastructure (V2I and I2V communication). • **Security of vehicle controls** – major concerns have been expressed over the need to ensure that vehicle controls are secure so that the risk of self-driving vehicles being able to be used for malicious intent (e.g. a deliberate of opportunistic attack on critical infrastructure and/or endangerment of human life and society) is minimised. • **'Free data'** - in-vehicle cameras in self-driving vehicles will record extensive road information that could be put to very good use by road network and infrastructure practitioners – the challenge then becomes how best to secure, transfer, analyse and store this valuable information.

- **Privacy and security of data** – it needs to be determined who, in addition to road network professionals will be able to access data coming from self-driving vehicles and what it will be used for. Effective legislation/regulation and practical controls are likely to be needed.
- **The freight task –** self-driving trucks are currently being developed and trialled (platooning etc.), and the freight industry is keen to contribute and even lead. Change will ultimately need to be gradual and considered as it will have a big effect on the freight industry, bringing down costs (possibly by as much as a third) and reducing driver numbers. It is recognised that the freight industry is already embracing in-vehicle safety technologies, gaining many benefits, and is therefore committed to the way ahead.
- **Role of motoring clubs** – motoring clubs have over 7 million members in Australia and offer a diverse range of services, including traditionally providing road users/vehicle owners with roadside (breakdown and incident) assistance and insurance. Given that the incidence of crashes is expected to reduce as fleet composition changes and perhaps reach zero with an entire self-driving fleet, motoring clubs may have to find alternative business avenues and models to stay relevant. It is possible that this could include vehicle ownership/rental opportunities. Indeed it was suggested that a national no-fault compensation scheme would be by far the simplest and most efficient insurance model once self-driving vehicles predominate, moving considerable business from commercial insurers.

Key stakeholders/agencies

Likely to include, but not restricted to: federal and state governments, including transport agencies, legal/justice departments and security advisors; police, legal professionals, motoring clubs/freight industry, advocacy groups, vehicle manufacturers.

Potential/possible solutions

While general patterns and trends can be foreseen, the precise timeframe and technology are not yet clear with the potential to be extremely significant. Views about the transport future are divergent – everyone has their own unique standpoint, based on their needs and aspirations. In terms of vehicle technology, Australia's remoteness and modest market size mean that inevitably other markets will shape the evolution of vehicles in Australia.

Australia could gain the greatest advantage by proactive, e.g. rapidly enabling the uptake of new technology and vehicles through trials and quickly identifying (and resolving) pressure points to future uptake. The road network of Australia affords excellent opportunities for self-driving vehicle trials. Freight industry trials can be conducted on regional roads where traffic is relatively sparse, roads are open and distances large. Urban trials should be considered on freeways and roads where infrastructure provision, e.g. lane markings and signage, are typically in line with world best practice.

Action required

- Develop and widely disseminate information on self-driving vehicles and the infrastructure features they rely on to operate safely and efficiently (and hence a clear view of the likely evolutionary stages of a road towards a totally self-driving operation) which will greatly assist legislators, regulators, road agencies and the general public.
- Remove regulatory barriers to self-driving vehicle trials in Australia.
- Identify vehicle manufacturers who are keen to engage in trials of their evolving vehicles (and particularly self-driving vehicles) and are looking for suitable sites.
- Establish and sustain a national information repository.

Analysis/commentary

There is uncertainty around when self-driving vehicles will become fully implemented , and how this will need to be phased in with V2V, V2I, I2V and high accuracy GPS. Footage of self-driving vehicles operating on roads now can be unhelpful, making it seem that this new technology is not dependent on infrastructure. A clearer message about the state of the technology and how it will need to integrate with infrastructure is suggested.

The ownership model of self-driving vehicles will undoubtedly impact on traffic volumes and flows in Australia's cities. The expectation is that the impact will be positive, but it will take time. At evening peak usage times in the US, only 12% of privately owned vehicles are in use at any given time (*KPMG & CAR 2012*). This points to the potential for the total number of vehicles to be dramatically reduced while maintaining or increasing total commuter travel distances.

A large part of the Australian freight task is taken up by multi-combination vehicles which already give greater safety (per ton kilometre) and greater productivity (per driver) than many countries developing self-driving systems. Adapting self-driving systems to the added complexity of multi-combination vehicles is a unique challenge for Australia. This is because the high cost of freight in Australia reduces international competitiveness - any cost advantage brought about by self-driving vehicles will have a significant flow-on effect for the national economy. Acting now will see Australia continuing to reap the rewards.

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5 Human issues – the users of self-driving vehicles

This section covers the human issues as they relate to the users of self-driving vehicles, from admission to the system (licensing) and training, to conformity and penalties for non-compliance with legislation.

Topic Human issues – the users of self-driving vehicles, fitness to drive, legal framework and conformity
Current position and future issues and challenges • **Personal legal vulnerability/liability** – as shown in Figure 2 and Figure 3 some degree of human input to the routine driving task and/or providing manual emergency back-up will be required for the foreseeable future (the 'nominal driver' concept). This will in turn retain some degree of duty of care by the nominal driver. With totally self-driving vehicles it would seem likely, and perhaps reasonable, for any legal vulnerability/liability to transfer to the vehicle manufacturer and its associated systems. • **Driver training** – it is not yet clear whether the re-training of all drivers will be required in moving towards self-driving vehicles or whether existing driving experience and skills will be recognised. Whatever is ultimately decided, this will require initial implementation and on-going management. The precise training requirements (e.g. method, time period etc.) to become a user of a self-driving vehicle also need to be determined. • **Performance/conformity/penalties** – the current system of demerit points is well embedded in Australia. How much this will need to change during the staged emergence of self-driving vehicles will need to be determined. This will include determination of what offences might need to exist for nominal drivers. • **Admission to system/fitness to drive** – the current Australia-wide graduated licencing scheme is well embedded and understood. Transition from driven to self-driving vehicles will be required, raising the question whether current licences will permit usage of a vehicle requiring some degree of driving and/or a self-driving vehicle? It is not clear whether licences will ultimately be needed at all for self-driving vehicles (other than just to provide a proof of identity). Age, health and experience standards need also to be considered for both mixed fleets and an entire fleet of self-driving vehicles. Whether pre-admission testing would still be required is up for debate. Similarly, it is not clear whether specialist licences might be needed for say, users of self-driving heavy goods vehicles, or whether a licence might cover all self-driving vehicle types. It is suggested that change in this area will be slow, and that a nominal driver will be required for some time to come, but it is opined that consideration and debate are needed now to clearly shape the way ahead. Some concern was expressed that developments in legislation. overseas will inevitably decide what occurs in Australia and it is suggested that the industry needs to be aware of this and monitor and understand developments outside of Australia. • **Impairment/distraction** – A fundamental issue is determining the level of impairment and/or distraction that would be legally allowed and also accepted by society when using a self-driving vehicle. Survey findings (UMTRI 2014) show that 43.3% of Australians would 'watch the road anyway' if they were being transported in a self-driving vehicle, as opposed to the US with 35.5%. This points to a current level of mistrust of the technology among the community although in the same survey Australians were more likely to want autonomous features in their cars than US respondents. The extent of change from the current position is likely to involve lengthy debate across a series of stakeholders and interest groups.

Key stakeholders/agencies

Likely to include, but not restricted to: federal and state governments, including transport agencies and legal / justice departments; police, legal professionals, motoring clubs/freight industry, advocacy groups, vehicle manufacturers.

Potential / possible solutions:

- **Admission to system/fitness to drive.** Changes would most likely be in the final stage of vehicle automation (totally self-driving vehicles), given that it is unlikely that requirements will be relaxed until control system reliability is near absolute. It is possible that some routes/networks may be implicitly less well suited to autonomous vehicle operation and as a result a restricted access model may be best suited in such circumstances.
- **Driver training** – knowledge of how and when an autonomous vehicle fails to cope with sensory information, and possible implications, will ultimately determine whether 'control' will be returned to a nominal driver and this in turn will determine what type and level of training is likely to be required.
- **Performance/conformity/penalties** – it is expected that such issues can only be finalised once it is established who is in control of a self-driving vehicle and where incidents can foreseeably occur, if any. In-vehicle systems recording and reporting position and state etc. around the time of an infringement or incident may be required. Ensuring that a self-driving vehicle is legal and functioning correctly before commencing a journey, or in the case of a vehicle with a 'driving function' handing over full control, is also likely to require further consideration.

Research required

- Assess the effect of varying the level of control between a vehicle and the driver/nominal driver for foreseeable safety risks, with a view to legislation.
- Determine standard protocols for recording and reporting who is in control of a vehicle at any time and the precise location of the vehicle.

Analysis/commentary

Concerns have been expressed about the potential need for rapid handover of control from the automatic system back to the nominal driver in the case of an emergency, system confusion or system malfunction, and how this is best achieved. This is especially the case with the higher automation levels where combined automation can be active on steering, braking and throttle which enables the driver to focus on other tasks for prolonged periods. Issues include:

- The time available to take control and react appropriately may be seconds or less in an emergency.
- Specific training for hand-back of control would be required.
- De-skilling of drivers for manual control of vehicles may occur in the long-term.
- A regulatory approach of requiring a driver to be ready to take control at all times may not be an effective measure or have community support.

It is also noted that self-driving vehicles are unable to make a *value judgement* between various outcomes if a collision becomes inevitable, e.g. a kangaroo hopping into the path of a vehicle may need a different strategy than a child running onto the road. Human control of a vehicle may be preferred as long as the 'driver' is prepared to do so through knowledge, skills and experience. Whether the responsibility of the vehicle's system is to prioritise the safety of the occupant, or all parties involved in a crash, and what liability issues this raises need to be resolved. The incident data that self-driving vehicles are required to store thirty seconds prior to an incident also needs consideration (California legislation SB 1298). This data could potentially be used in court against the human driver when in control of the vehicle. While 96% of new car sales in the US are fitted with similar incident logging features, the data in the case of self-driving vehicles is far more detailed and can paint an accurate picture of liability in an incident.

6 Conclusions

The challenges facing Australia with the emergence of self-driving vehicles are perhaps more far reaching and immediate than many recognise.

It is important that Australia's position of being an end consumer of self-driving vehicles does not dictate the local networks of the future. Australia has its own unique transport challenges and needs and making self-driving vehicles work is the key – e.g. by increasing network capacity and efficiency and reducing freight costs.

The infrastructure and systems that are built today are likely to remain for many years beyond the introduction of self-driving vehicles, and it is imperative that we plan for these systems now taking into account their very different needs. Australia must respond to the challenges quickly and in an integrated way. Planning and being ready for the foreseeable future is only one part of the response. Having a vision for the future and building the system in a logical way will also be vital, as current uncertainties are researched, monitored and become clearer in time.

While it is obvious that many organisations have done excellent work on many aspects of the self-driving vehicles (including how they might impact directly on, and ultimately shape Australian society and life) it is clear that an increased amount of collaboration would be very beneficial. This is a great opportunity – with active collaboration between government, industry, research providers, community organisations and many other bodies focused on promoting structure, certainty, accountability and efficiency, it will ensure that Australia is prepared for the introduction and evolution of self-driving vehicles.

To create effective policy and long-term plans, and to ensure that effective legislative and regulatory mechanisms are in place to facilitate that policy, and make Australia increasingly competitive, policy makers need to be well informed and have a clear understanding about the self-driving vehicles future. ARRB is committed to assist stakeholders in this process to ensure that Australia has the forward plans and policies needed to give clarity to the issue. ARRB also commits to ensure that stakeholders are given support for the correct information to be disseminated to the Australian public. A vehicle fleet comprising only self-driving vehicles can be foreseen, and although it is very much an ultimate goal (perhaps some 30 to 40 years away), a number of highly important operational and preparatory stages must take place.

It is our intention to identify and organise further events and opportunities for collaboration relating to this initiative throughout 2015 and beyond including an Australian demonstration project.

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Appendix A – Attendees at the self-driving vehicle workshop

The following attended the self-driving vehicle workshop at the ARRB Conference (Sydney) held on the morning of Wednesday 22 October 2014 (listed in alphabetical order by surname):

Name	Position	Organisation
Ian Webb (facilitator)	Chief Executive	Roads Australia
Nicholas Clarke	Chief Executive Officer	ANCAP
Stuart Ballingall	Project Director Cooperative ITS	Austroads
Carl Liersch	General Manager, Chassis Systems Control	Bosch Australia
John Wall	Manager Road Safety Technologies	Centre for Road Safety
Michael Sutton	General Manager Land Transport Productivity	Dept. Infrastructure and Regional Development
Ljubo Vlacic	Director, Intelligent Control Systems Laboratory	Griffith University
Allan Gray	Senior Account Manager	IHS Automotive
Susan Harris	Chief Executive Officer	ITS Australia
Glenn Geers	Technology Director, Infrastructure Transport & Logistics	National ICT Australia
Chris Siorokos	General Manager Corporate Affairs	National Roads & Motorist Association
Marcus Burke	Project Director - Heavy Vehicle Compliance and Technology	National Transport Commission
Craig Moran	General Manager, Road Network Operations	Road and Maritime Services
Penny Gale	General Manager Public Affairs	Royal Automobile Association (RAA) South Australia
Dave Jones	Manager Roads and Traffic	Royal Automobile Club Victoria
Fred Curtis	General Manager Local & Data Group	Sensis
David Simon	Managing Director (Immediate Past Chair ATA)	Simon National Carriers
James Holyman	Director Business Strategy and Planning	Taxi Services Commission
Dennis Walsh	Deputy Chief Engineer (Road Operations)	Transport and Main Roads
Mike Regan	Professor	University of New South Wales
Garry Bowditch	Chief Executive	University of Wollongong (SMART Infrstructure Facility)
Dean Zabrieszach	Director Road Operations	VicRoads
David Pickett	Technical Manager	Volvo Car Australia
Peter Divjakinja	National Risk Manager - Motor	Wesfarmers Insurance
ARRB Staff		
Gerard Waldron	Managing Director	ARRB Group
Peter Damen	General Manager Research and Consulting	ARRB Group
Charles Karl	Manager, Congestion, Freight and Productivity	ARRB Group
Paul Hillier (reporter)	National Technical Leader, Incident Investigations & Reviews, Safe Systems	ARRB Group
Bob Wright (reporter)	Engineer, Freight & Heavy Vehicles, Congestion, Freight and Productivity	ARRB Group
Georgia Whiteside (administrator)	Personal Assistant to the General Manager	ARRB Group

Apologies were received from the following:

Name	Position	Organisation
Lauchlan McIntosh	Chairman ANCAP	ANCAP/ACRS
Craig Newland	Director Technical Services	Australian Automobile Association
Stuart St Clair	Chief Executive	Australian Trucking Association
Bernard Soriano	Deputy Director	California DMV
Margaret Prendergast	General Manager, Business Strategy and Strategic Projects	Centre for Road Safety
Ian Collings	Deputy Chief Research	CSIRO CC Division
Judith Zielke	Deputy Coordinator	Dept. Infrastructure and Regional Development
James Hurnall	Technical Director	Federal Chamber of Automotive Industries
Richard Suhr	Director. Google Enterprise Geo	Google Enterprise
Ryan Caudle	Industry Lead, Information Technology and Services	Google Enterprise
Rohan Fernando	Enterprise Business Development - Oceania	HERE
Stephen Troughton	Managing Director	Main Roads Western Australia
Rob Fitzpatrick	Director, Infrstructure Transport and Logistics	National ICT Australia
Paul Retter	Chief Executive Officer	National Transport Commission
Greg Lilleyman	Group Exectuive, Technology and Innovation	Rio Tinto
David Stuart Watt	President Roads Australia	Roads Australia
Patrick Walker	Executive General Manager , Advocacy and Member Benefits	Royal Automobile Club (RAC) Western Australia
Brian Negus	Regional Manager	Royal Automobile Club Victoria
Mat Clee	Senior Business Manager Parking	Scentre Group
Ron Glenn	Manager Systems Projects, Industrial Projects	Thiess
Sarah Jones	Group Manager Road Transport Compliance	Toll Group
Neil Scales	Director General	Transport and Main Roads
Lisa Tobin	Group General Manager Technology	Transurban Group
Kevin Dopart	Program Manager - Vehicle Safety & Automation	US DOT
Trent Victor	Senior Technical Leader Crash Avoidance	Volvo Car Corporation